CLAIMS

We claim:

1. A phase shift device, comprising:

a first superconducting terminal, having a first phase;

a second superconducting terminal, having a second phase; and

a phase shifter, coupled to the first superconducting terminal and to the second superconducting terminal, wherein

the phase shifter is capable of causing a predefined difference between the first phase and the second phase.

2. The phase shift device of claim 1, wherein

the phase shifter comprises an anisotropic superconductor.

3. The phase shift device of claim 2, wherein

the anisotropic superconductor is a d-wave superconductor.

4. The phase shift device of claim 2, wherein

the first superconducting terminal and the second superconducting terminal comprise s-wave superconductors.

5. The phase shift device of claim 2, wherein

the anisotropic superconductor is coupled to the first superconducting terminal through a first side; and

the anisotropic superconductor is coupled to the second superconducting terminal through a second side; wherein

the first side and the second side define a mismatch angle.

6. The phase shift device of claim 5, wherein

the mismatch angle is about 90 degrees.

7. The phase shift device of claim 2, wherein

the phase shifter is electrically coupled to the first superconducting terminal through a first connector; and

the phase shifter is electrically coupled to the second superconducting terminal through a second connector.

8. The phase shift device of claim 7, wherein

the first superconducting terminal, the second superconducting terminal, the first connector, the second connector, and the phase shifter overlie a substrate.

9. The phase shift device of claim 8, wherein

the first connector is adjacent to the phase shifter;

the first superconducting terminal is adjacent to the first connector;

the second connector is adjacent to the phase shifter; and

the second superconducting terminal is adjacent to the second connector.

10. The phase shift device of claim 7, wherein

the first connector and the second connector comprise normal metals.

11. The phase shift device of claim 2, wherein

the length and the width of the first superconducting terminal and the length and the width of the second superconducting terminal are less than about 5 microns, wherein

the first superconducting terminal and the second superconducting terminal have length and width.

12. The phase shift device of claim 2, wherein

the coupling of the phase shifter and the first superconducting terminal comprises a first Josephson junction; and

the coupling of the phase shifter and the second superconducting terminal comprises a second Josephson junction.

13. The phase shift device of claim 2, wherein

the first superconducting terminal and the second superconducting terminal comprise niobium, aluminum, lead, or tin;

the phase shifter comprises $YBa_2Cu_3O_{7-d}$, wherein d has a value between about 0 and about 0.6; and

the first connector and the second connector comprise gold, silver, or platinum.

14. The phase shift device of claim 2, wherein the phase shifter comprises:

a plurality of anisotropic superconductors.

15. The phase shift device of claim 14, wherein the phase shifter comprises:

a first anisotropic superconductor; and

a second anisotropic superconductor, wherein

the first superconductor and the second superconductor are coupled by a Josephson-junction.

16. The phase shift device of claim 15, wherein the Josephson-junction comprises:

a grain boundary.

17. The phase shift device of claim 15, wherein

the first anisotropic superconductor has a first order parameter with a first orientation, and

the second anisotropic superconductor has a second order parameter with a second orientation, wherein

the first orientation and the second orientation define a mismatch angle.

18. The phase shifter device of claim 17, wherein the mismatch angle is about 45 degrees.

19. The phase shift device of claim 15, wherein the first anisotropic superconductor and the second anisotropic superconductor overlie a substrate.

20. The phase shift device of claim 19, wherein the first connector overlies the first anisotropic superconductor; and the second connector overlies the second anisotropic superconductor.

21. The phase shift device of claim 20, wherein the first superconducting terminal overlies the first connector; and the second superconducting terminal overlies the second connector.

22. The phase shift device of claim 1, wherein the phase shifter comprises: a ferromagnet.

23. The phase shift device of claim 22, wherein the ferromagnet is an alloy of copper and nickel.

24. The phase shift device of claim 22, wherein the first superconducting terminal overlies a substrate; the ferromagnet overlies the first superconducting terminal; and the second superconducting terminal overlies the ferromagnet.

25. The phase shift device of claim 24, wherein

the second superconducting terminal is isolated from the first superconducting terminal by an insulator.

26. The phase shift device of claim 25, wherein

the insulator is polymethylmethacrylate or AlO_x, wherein x is an integer.

27. The phase shift device of claim 24, wherein

the length and width of the first superconducting terminal, the ferromagnet and the second superconducting terminal, and

the relative position of the first superconducting terminal, the ferromagnet and the second superconducting terminal is such that they cause a predefined difference between the first phase and the second phase, wherein

the first superconducting terminal, the ferromagnet and the second superconducting terminal have a length, a width, and a relative position.

28. The phase shift device of claim 22, wherein

the first superconductor terminal and the second superconductor terminal are coupled by a junction area; and

the ferromagnet is embedded in the junction area.

29. The phase shift device of claim 28, wherein

the length and width of the first superconducting terminal, the ferromagnet and the second superconducting terminal, and

the relative position of the first superconducting terminal, the ferromagnet and the second superconducting terminal is such that they cause a predefined difference between the first phase and the second phase, wherein

the first superconducting terminal, the ferromagnet and the second superconducting terminal have a length, a width, and a relative position.

30. The phase shift device of claim 1, further comprising:

a conventional superconducting terminal, coupled to the first superconducting terminal by a first junction, and coupled to the second superconducting terminal by a second junction,

the first superconducting terminal, the second superconducting terminal, and the conventional superconducting terminal forming a loop.

31. The phase shift device of claim 30, wherein

the first and second junctions are c-axis heterojunctions.

32. The phase shift device of claim 30, wherein

the predefined difference between the first phase and the second phase is about $\pi/2$.

33. A phase shift device, comprising:

a first superconducting terminal means, having a first phase;

a second superconducting terminal means, having a second phase; and

a phase shifter means, coupled to the first and second superconducting terminal means, capable of causing a predefined difference between the first phase and the second phase.

34. The phase shift device of claim 33, wherein

the phase shifter means comprise a d-wave superconductor.

35. A phase shifting method, the method comprising:

providing a first superconducting terminal, having a first phase;

providing a second superconducting terminal, having a second phase; and

coupling a phase shifter to the first superconducting terminal and to the second superconducting terminal, wherein

the phase shifter is capable of causing a predefined difference between the first phase and the second phase.

36. The method of claim 35, wherein providing a phase shifter comprises:

providing an anisotropic superconductor.

37. The method of claim 35, wherein coupling the phase shifter comprises:

coupling the first superconducting terminal to a first side of the phase shifter;

coupling the second superconducting terminal to a second side of the phase shifter, wherein

the first side and the second side of the phase shifter define a mismatch angle.

38. The method of claim 37, wherein

coupling the first superconducting terminal to the first side of the phase shifter comprises:

coupling the first superconducting terminal to a first connector, and

coupling the first connector to the phase shifter; and

coupling the second superconducting terminal to the second side of the phase shifter comprises:

coupling the second superconducting terminal to a second connector, and

coupling the second connector to the phase shifter.

39. The method of claim 35, wherein providing the phase shifter comprises:

providing a first anisotropic superconductor, having a first order parameter with a first orientation, and

providing a second anisotropic superconductor, having a second order parameter with a second orientation, wherein

the first orientation and the second orientation define a mismatch angle.

40. The method of claim 35, wherein providing the phase shifter comprises:

coupling the first superconducting terminal and the second superconduting terminal with a junction; and

providing a ferromagnet in the junction.

41. A phase shifter circuitry, comprising:

a phase shift device, comprising:

a first superconducting terminal, having a first phase;

a second superconducting terminal, having a second phase; and

a phase shifter, coupled to the first superconducting terminal and to the second superconducting terminal, wherein

the phase shifter is capable of causing a predefined difference between the first phase and the second phase; and

superconducting circuitry, coupled to the phase shift device.

42. The phase shifter circuitry of claim 41, wherein

the phase shifter comprises an anisotropic superconductor.

43. The phase shifter circuitry of claim 41, wherein

the anisotropic superconductor is coupled to the first superconducting terminal through a first side; and

the anisotropic superconductor is coupled to the second superconducting terminal through a second side; wherein

the first side and the second side define a mismatch angle.

44. The phase shifter circuitry of claim 41, wherein

the phase shifter is electrically coupled to the first superconducting terminal through a first connector; and

the phase shifter is electrically coupled to the second superconducting terminal through a second connector.

45. The phase shifter circuitry of claim 41, wherein

the first superconducting terminal and the second superconducting terminal comprise niobium, aluminum, lead, or tin;

the phase shifter comprises $YBa_2Cu_3O_{7-d}$, wherein d has a value between about 0 and about 0.6; and

the first connector and the second connector comprise gold, silver, or platinum.

46. The phase shifter circuitry of claim 41, wherein the phase shifter comprises:

a first anisotropic superconductor, having a first order parameter with a first orientation; and

a second anisotropic superconductor, having a second order parameter with a second orientation, wherein

the first orientation and the second orientation define a mismatch angle; and

the first superconductor and the second superconductor are coupled by a Josephson-junction.

47. The phase shifter circuitry of claim 41, wherein

the first anisotropic superconductor and the second anisotropic superconductor overlie a substrate;

the first connector overlies the first anisotropic superconductor;

the second connector overlies the second anisotropic superconductor;

the first superconducting terminal overlies the first connector; and

the second superconducting terminal overlies the second connector.

48. The phase shifter circuitry of claim 41, wherein

the first superconducting terminal overlies a substrate;

a ferromagnet overlies the first superconducting terminal; and

the second superconducting terminal overlies the ferromagnet.

49. The phase shifter circuitry of claim 48, wherein

the first superconductor terminal and the second superconductor terminal are coupled by a junction area; and

the ferromagnet is embedded in the junction area.

50. The phase shifter circuitry of claim 41, wherein

the phase shift device overlies a substrate;

the superconducting circuitry overlies the phase shift device; and

a first contact terminal and a second contact terminal couples the superconducting circuitry and the phase shift device.

51. The phase shifter circuitry of claim 50, wherein

the substrate is sapphire or $SrTiO_3$.

52. The phase shifter circuitry of claim 50, wherein

an insulating layer separates the phase shift device and the superconducting circuitry, wherein

the first contact terminal and the second contact terminal couples the superconducting circuitry and the phase shift device through a first opening and a second opening in the insulating layer, respectively.

53. The phase shifter circuitry of claim 41, wherein

the superconducting circuitry overlies a substrate;

the phase shift device overlies the superconducting ciruitry; and

a first contact terminal and a second contact terminal couples the superconducting circuitry and the phase shift device.

54. The phase shifter circuitry of claim 53, wherein

an insulating layer separates the phase shift device and the superconducting circuitry, wherein

the first contact terminal and the second contact terminal couples the superconducting circuitry and the phase shift device through a first opening and a second opening in the insulating layer, respectively.

55. The phase shift circuitry of claim 41, wherein the superconducting circuitry comprises:

quantum computing circuitry.

56. A phase shifter circuitry, comprising:

a phase shift device means, comprising:

a first superconducting terminal means, having a first phase;

a second superconducting terminal means, having a second phase; and

a phase shifter means, coupled to the first and second superconducting terminal means, capable of causing a predefined difference between the first phase and the second phase;

and

a superconducting circuitry means, coupled to the phase shifting means.

57. A phase shifting method, the method comprising:

providing a phase shift device, comprising:

providing a first superconducting terminal, having a first phase;

providing a second superconducting terminal, having a second phase; and

coupling the first superconducting terminal and the second superconducting terminal to a phase shifter, wherein

the phase shifter is capable of causing a predefined difference between the first phase and the second phase; and

coupling a superconducting circuitry to the phase shift device.

58. The method of claim 57, wherein providing a phase shifter comprises:

providing an anisotropic superconductor.

59. A phase shifter chip, comprising:

a plurality of phase shift devices, the phase shift devices individually comprising:

a first superconducting terminal, having a first phase;

a second superconducting terminal, having a second phase; and

a phase shifter, coupled to the first superconducting terminal and to the second superconducting terminal, wherein

the phase shifter is capable of causing a predefined difference between the first phase and the second phase; and

superconducting circuitry, coupled to the plurality of phase shift devices.

60. The phase shifter chip of claim 59, wherein the phase shifters individually comprise:

an anisotropic superconductor.

61. The phase shifter chip of claim 59, wherein

the first superconducting terminals and the second superconducting terminals comprise niobium, aluminum, lead, or tin; and

the phase shifters individually comprise $YBa_2Cu_3O_{7-d}$, wherein d has a value between about 0 and about 0.6.

62. The phase shifter chip of claim 59, wherein the phase shifters individually comprise:

a first anisotropic superconductor, having a first order parameter with a first orientation; and

a second anisotropic superconductor, having a second order parameter with a second orientation, wherein

the first orientation and the second orientation define a mismatch angle.

63. The phase shifter chip of claim 62, wherein

the mismatch angle is about 45 degrees.

64. The phase shifter chip of claim 59, wherein in the individual phase shifters

the first anisotropic superconductors and the second anisotropic superconductors are coupled by a Josephson-junction.

65. The phase shifter chip of claim 64, wherein

the Josephson junctions comprise a grain boundary.

66. The phase shifter chip of claim 59, wherein in the individual phase shift devices

the first anisotropic superconductor and the second anisotropic superconductor overlie a substrate;

the first superconducting terminal overlies the first anisotropic superconductor; and

the second superconducting terminal overlies the second anisotropic superconductor.

67. The phase shifter chip of claim 59, wherein

the plurality of phase shift devices overlie a substrate;

the superconducting circuitry overlies the plurality of phase shift devices; and

the individual phase shift devices are coupled to the superconducting circuitry by first contact terminals and second contact terminal.

68. The phase shifter chip of claim 67, wherein

an insulating layer separates the plurality of phase shift devices and the superconducting circuitry, wherein in the individual phase shift devices

the first contact terminal and the second contact terminal couples the superconducting circuitry and the individual phase shift device through a first opening and a second opening in the insulating layer, respectively.

69. The phase shifter chip of claim 59, wherein

the superconducting circuitry overlies a substrate;

the plurality of phase shift devices overlie the superconducting ciruitry; and

the individual phase shift devices are coupled to the superconducting circuitry by first contact terminals and second contact terminals.

70. The phase shifter chip of claim 69, wherein

an insulating layer separates the plurality of phase shift devices and the superconducting circuitry, wherein in the individual phase shift devices

the first contact terminal and the second contact terminal couples the superconducting circuitry and the individual phase shift device through a first opening and a second opening in the insulating layer, respectively.

71. The phase shifter chip of claim 59, wherein the superconducting circuitry comprises:

quantum computing circuitry.

72. A phase shifter chip, comprising:

a plurality of phase shift device means, the individual phase shift devices comprising:

a first superconducting terminal means, having a first phase;

a second superconducting terminal means, having a second phase; and

a phase shifter means, coupled to the first and second superconducting terminal means, capable of causing a predefined difference between the first phase and the second phase; and

a superconducting circuitry means, coupled to the plurality of phase shifting means.

73. A method of making a phase shifter chip, the method comprising:

forming a substrate with a first crystal axis orientation;

forming a seed layer with a second crystal axis orientation, overlying the substrate, wherein the second crystal axis orientation is different from the first crystal axis orientation,

forming a plurality of openings in the seed layer; and

forming a plurality of phase shift devices overlying the plurality of openings.

74. The method of claim 73, wherein the forming of a plurality of phase shift devices comprises:

forming a plurality of first anisotropic superconductors over the plurality of openings; and

forming a plurality of second anisotropic superconductors over the seed layer.

75. The method of claim 74, wherein the forming of a plurality of phase shift devices comprises:

forming a plurality of first anisotropic superconductors, having first order parameters with a first orientation; and

forming a plurality of second anisotropic superconductors, having second order parameters with a second orientation, wherein

the first orientation is determined by the first crystal axis orientation; and

the second orientation is determined by the second crystal axis orientation.